

# Mapping of metal contaminants in photovoltaic grade silicon by X-ray fluorescence

W. Seifert<sup>1,2</sup>, S.A. McHugo<sup>3</sup>, A.C. Thompson<sup>4</sup>, H.J. Moeller<sup>1</sup> and E.R. Weber<sup>2</sup>

<sup>1</sup>Institute of Experimental Physics, Technical University of Freiberg,  
09596 Freiberg, Germany

<sup>2</sup>Department of Materials Science and Mineral Engineering, University of California,  
Berkeley, California 94720, USA

<sup>3</sup>Advanced Light Source, Ernest Orlando Lawrence Berkeley National Laboratory,  
University of California, Berkeley, California 94720, USA

<sup>4</sup>Center for X-Ray Optics, Ernest Orlando Lawrence Berkeley National Laboratory,  
University of California, Berkeley, California 94720, USA

## INTRODUCTION

Photovoltaic grade polycrystalline silicon is widely used for solar cell fabrication because of cost considerations. However, the conversion efficiency of such cells is still clearly lower than that of more expensive, high quality monocrystalline cells. The primary cause for the poorer performance is regions of strong carrier recombination, caused by high densities of extended crystal defects. It is generally accepted that transition metals play an important part since it is known that “clean” extended defects cause only weak carrier recombination while transition metal decoration increases the recombination activity greatly [1-3]. Therefore, identification of transition metals in solar grade silicon and assessment of their impact on the recombination properties is crucial to further improving the performance of polycrystalline solar cells.

## EXPERIMENTS

Boron doped polycrystalline Si material grown by the rapid growth on substrate (RGS) method was used in the study. Minority carrier recombination was mapped with the light beam induced current (LBIC) and electron beam induced current (EBIC) methods. On the basis of high spatial resolution EBIC maps, regions of high carrier recombination were chosen for x-ray fluorescence mapping. Prior to the XRF measurements, the samples were carefully cleaned with Piranha clean. The measurements were carried out on the XRF equipment at beamline 10.3.1. The equipment uses a focused 12.5 keV monochromatic radiation and a Si-Li detector to measure the fluorescence from the sample. The sampling depth for 3d transition metals in silicon is approximately 50  $\mu\text{m}$ . The spatial resolution was about  $1.5 \times 2 \mu\text{m}^2$ , which allows to detect a single Fe precipitate greater than 10-20 nm in radius.

## RESULTS AND DISCUSSION

Fig. 1 shows an EBIC recombination map of a polycrystalline silicon sample. Dark regions correspond to high recombination, bright regions to low recombination. Note the dark region with a bright center in the central part of the image. X-ray fluorescence measurements taken in the region denoted by the box revealed a small

Fig. 1: EBIC image of a portion of a polycrystalline silicon sample. The box denotes the area analyzed with x-ray fluorescence.

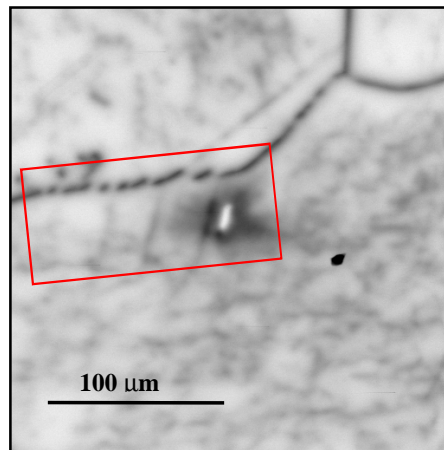
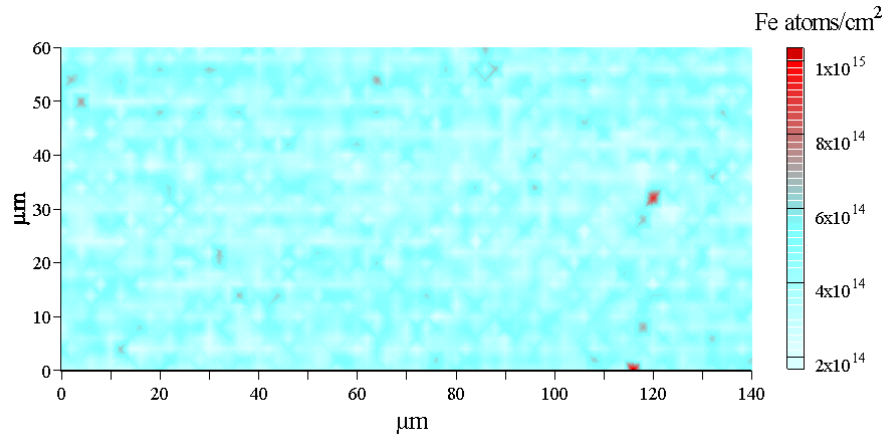


Fig. 2: Fe distribution in the area marked by the box in Figure 1.



amount of iron slightly above the background noise level in this region. (Fig.2). No other transition metals were detected.

Unlike previously reported results on polycrystalline silicon [4,5], in most samples with regions of high carrier recombination the transition metal content was below the detection limit of the XRF system. This indicates an improvement of the metal impurity level in the photovoltaic grade silicon. Despite the reduction of metal content, carrier recombination may still be high since, according to past work [2], small amounts of transition metals may be sufficient to increase the recombination activity of extended defect considerably. Another possible cause for high carrier recombination is precipitation of oxygen or carbon since these impurities are present in very high concentrations ( $\approx 10^{18} \text{ cm}^{-3}$ ), but are not detected by the XRF system. Therefore, an upgrade of the system for detection of light elements would be very helpful for future studies.

## REFERENCES

1. T.S. Fell, P.R. Wilshaw, and M.D. d. Coteau, Phys. Status Solidi A **138**, 695 (1993).
2. M. Kittler, C. Ulhaq-Bouillet, and V. Higgs, J. Appl. Phys. **78**, 4573 (1995).
3. W. Seifert, M. Kittler, and J. Vanhellemont, Mater. Sci. Engin. **B42**, 260 (1996).
4. S.A. McHugo, Appl. Phys. Lett. **71**, 1984 (1997).
5. S.A. McHugo, A.C. Thompson, I. Perichaud, and S. Martinuzzi, Appl. Phys. Lett. **72**, 3482 (1998).

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Science Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. Two of us (W. S. and H.J. M.) acknowledge support by the German Federal Ministry of Education and Science under Contract No. 0329743D.

Principal investigator: Eicke R. Weber. Email: weber@socrates.berkeley.edu  
 Contact also: Winfried Seifert, Email: weseifert@lbl.gov. Tel 510-486-6634.  
 Scott McHugo, Email: smchugo@grace.lbl.gov. Tel 510-486-2104.